Title: Monopropellant system

The present invention is in the area of monopropellant composition systems, for instance for spacecraft propulsion, in emergency systems for jet fighters or in emergency gasgeneration systems for submarines.

Spacecraft propulsion is defined as that needed for the orientation (attitude control) and positioning (orbit control including de-orbiting) of spacecraft after delivery into the required orbit by the launch vehicle. It is quite separate and distinct from launcher propulsion. The need for spacecraft propulsion begins with its separation from the launch vehicle and terminates at the end of its useful service life. It is usually the depletion of the spacecraft's propellant that terminates its mission.

Typical requirements for attitude and orbit control are very low thrust (0.1 N typically), a pulsed operational mode for attitude control, a continuous operational mode for orbit control and accurate and repeatable performance and reliable leak-free operation. For de-orbiting the thrust can be higher.

The propulsion in this area is amongst others generated by so-called monopropellant thrusters, wherein a propellant is catalytically or thermally decomposed into hot gases which are then expanded through a nozzle. In the area of monopropellants hydrogen peroxide and hydrazine are presently traditionally used. They provide a specific impulse of respectively 1872 and 2266 m/s at an expansion ratio of 50, zero ambient pressure, chamber pressure of 1 MPa and at chemical equilibrium outflow conditions.

Both systems have, however, some drawbacks. Hydrogen peroxide is known for its instability and

autodecomposition behaviour. Drawbacks of hydrazine are its toxicity and flammability.

These aspects of currently used monopropellants accordingly require high level, and thus costly, requirements for production, transport, storage, handling and disposal.

The same problems are encountered in emergency systems for jet fighters (emergency start-up of engine after flame-out) and submarines (emptying ballast tanks in emergency situation by generating gas).

It is one of the objects of the present invention to provide a monopropellant composition for spacecraft propulsion and the other uses described above, which obviates these drawbacks of the prior art system. It is a further object to provide a stable, clean, less toxic, and/or less flammable monopropellant composition. It is also an object to provide a monopropellant composition for spacecraft propulsion that could contribute to a relaxation of requirements and therefore to a reduction of costs and launch preparation time.

The present invention is based on the surprising finding that known solid high energy oxidisers such as hydrazinium nitroformate and ammonium dinitramide, when dissolved in water provide a liquid monopropellant system having a specific impulse that could be equal to the specific impulse of the conventional monopropellants, without having the disadvantages thereof.

The invention is accordingly directed to a solution of hydrazinium nitroformate and/or ammonium dinitramide in water and/or a lower alkanol as monopropellant composition, especially in spacecraft propulsion. The amount of water and/or lower alkanol in the system should be such that the system is liquid, which determines the lower level of the amount of water. On the other hand there should be sufficient hydrazinium nitroformate and/or ammonium dinitramide present in the system to provide the required impulse. Due to the nature of spacecraft propulsion, this specific impulse of the

propellant system should be as high as possible, in order to prolong the lifetime of the satellite.

According to a preferred embodiment hydrazinium nitroformate in water is used. In another embodiment of the propellant system according to the invention additionally an amount of an organic solvent, for example a lower alkanol, such as methanol, ethanol, propanol or butanol, can be used. It has been found that this increases the specific impulse of the monopropellant. The amount of alkanol in the solution is preferably between 0 and 70 wt.%, whereas methanol and/or ethanol are preferred.

An especially preferred system consists of 25 to 75 wt.% of hydrazinium nitroformate, 5 to 50 wt.% of water and 0 (more preferred 5) to 25 wt.% of lower alkanol.

In accordance with the invention it is also possible to include other additives in the propellant system, including, but not limited to solubilisers, vapour pressure decreasing agents and performance improving agents.

In another embodiment the present invention is directed to a process for orienting and positioning of spacecraft after delivery into the required orbit by a launch vehicle using a spacecraft propulsion system based on monopropellant thrusters, wherein the monopropellant discussed hereinabove is used for propulsion.

Hydrazinium nitroformate and ammonium dinitramide are known high energy solid oxidisers. The use of hydrazinium nitroformate as ingredient in high performance propellant combinations for rocket engines is for example disclosed in European patent application 350,136. A production process for hydrazine nitroformate is further disclosed in the international patent application WO-A 9410104. Ammonium dinitramide is also a known material, the production of which is for example disclosed in WO-A 9424073.

The monopropellants according to the invention can be used in the conventional way for spacecraft propulsion, in existing systems, whereby it is to be noted that due to the

properties of the system, less strict requirements concerning storage, transport and handling are possible.

Description of the figure.

The figure shows a comparison of specific impulse of various propellant systems.

The specific impulse of various monopropellant systems in accordance with the invention has been compared with the values for an aqueous solution of ammonium dinitramide and hydrazinium nitroformate in water, at 50 wt.% water. In the following table and in the figure the specific impulse is given for an expansion ratio of 50 and a chamber pressure of 1 MPa, zero ambient pressure and at chemical equilibrium outflow conditions.

Table 1

Ingredient	Specific Impulse m/s Based on 50% water and 50% oxidiser	For the pure oxidiser
Hydrazinium Nitroformate (HNF)	1754	2950
Ammonium Dinitramide (ADN)	1267	2319
Hydrogen Peroxide (H_2O_2)	1872	
Hydrazine (N_2O_4)	2266	

As can be seen in the table 50% oxidisers/water mixtures result in a performance loss compared to hydrogen peroxide and hydrazine. This performance loss may be acceptable in view of the reduction of cost due to simpler

procedures for production, transport, storage, handling and disposal. Furthermore, by increasing the amount of dissolved oxidiser the performance can be further increased. If fuels such as lower alkanols are added, performance equal to or even exceeding the performance of hydrazine is possible.

In the attached figure the specific impulse is given for various compositions of hydrazinium nitroform in water, using various concentrations, ammonium dinitramide in water using various concentrations and for a combination of hydrazinium nitroform, ethanol and water.

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